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Official Organ of

THE POTATO ASSOCIATION OF AMERICA

NEW BRUNSWICK, NEW JERSEY

THIRTY-EIGHTH ANNUAL MEETING

of

THE POTATO ASSOCIATION OF AMERICA

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December 11-12-13, 1951

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American Potato Journal

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DETERMINING THE SPECIFIC GRAVITY OF INDIVIDUAL POTATOES[1]

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(Accepted for publication July 12, 1951)

A report on the development of a specific gravity potato grader in Colorado was made in September, 1949. (1) Except for mention of certain features of the developments in Dr. Robert Kunkel's paper, nothing has been published on the method of determining specific gravity of individual tubers used in checking the grader.

For weighing the individual potatoes in air and in water, potatoes were hooked to a wire attached to the balance beam as shown in figure 1. A three bar balance weighing to 0.1 gram was used. A container of water was supported on a parallel motion stand, attached to the weighing table as shown. The weight was first taken in air; then, by pressing the foot treadle at right, the container of water was raised up around the tuber (note dotted line position) for weighing in water.

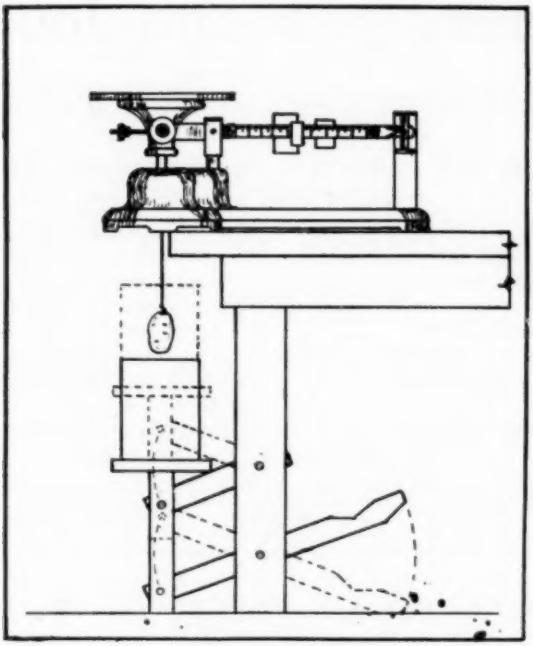

Fig. 1. Apparatus for weighing individual tubers.

The chart (Figure 2) was used in determining the specific gravity from the weights, by placing a transparent straight edge along the vertical weight in air line. Then the horizontal weight in water line intersected the straight edge at the inclined specific gravity line.

[1] Report of a study made under the Research and Marketing Act of 1946. For publication in the American Potato Journal.
[2] Senior Agricultural Engineer

Literature Cited

1. Kunkel, R. 1950. Gravity grading of potatoes. Amer. Potato Jour. 27:59-64.

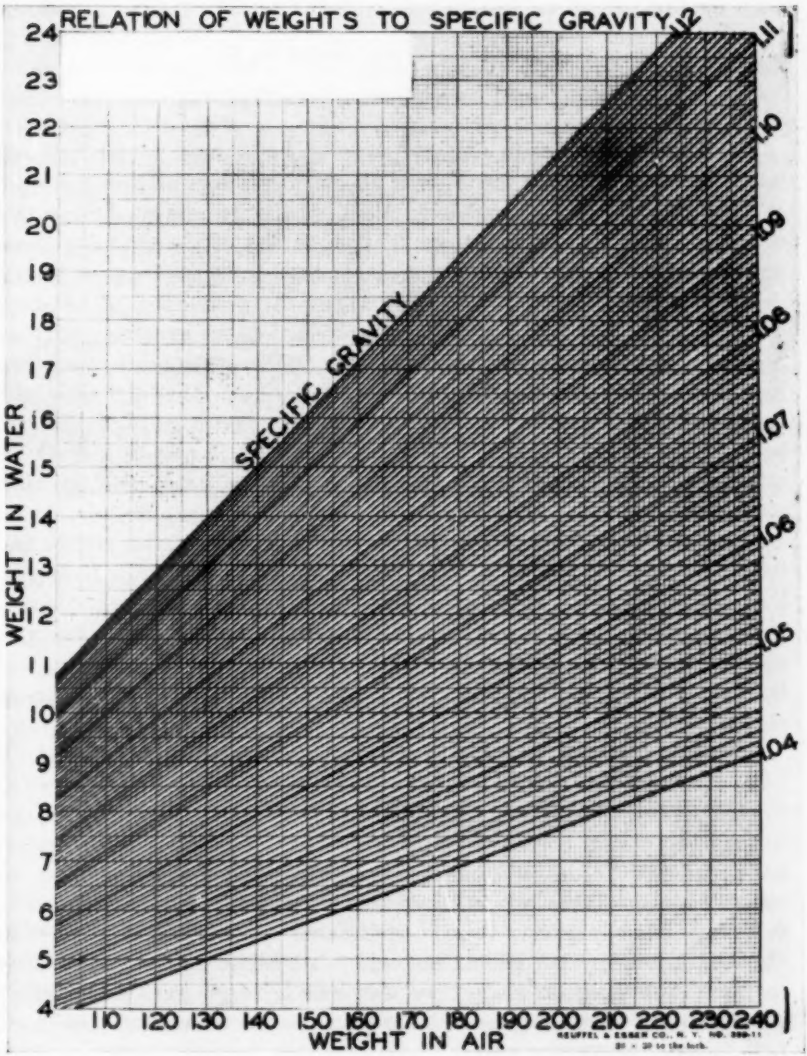

Fig. 2. Chart for determining specific gravity from weight of individual potatoes in air and in water.

POTATO QUALITY*

ORA SMITH

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(Accepted for publication June 21, 1951)

The subject of "Potato Quality" is of great interest to me and one which should receive the attention of all potato growers on this continent. We are very much concerned with potato quality because we believe that the quality of the potatoes on our markets is one of the most important reasons for the decline in consumption of potatoes during the past several decades. Almost constantly we hear about overproduction of potatoes, when the trouble is not necessarily overproduction but underconsumption. Not many years ago the average annual *per capita* consumption of potatoes in the United States was 240 lbs. Between 1938 and 1948 the *per capita* consumption of potatoes fell off 22 lbs. With a population of 150 million persons this means a reduction in consumption of 55 million bushels. In other words, if the 1938 rate had been maintained, the 1948 so-called overproduction would have been consumed in a normal manner. What U. S. grower would not like to see this occur? These potatoes can be and have been removed from the channels of trade by destroying or feeding to livestock or by making them into alcohol or starch. But this is economically unsound. Reduction in acreage is a commendable step and it will probably reduce the amount of potatoes to be sold but it will not in any way improve satisfaction to the consumer. That is the first big step this industry should take.

What's wrong with our potatoes? Too high a percentage do not meet the U. S. No. 1 grade. From 10 to 40 per cent or more of the potatoes grown in the United States usually do not meet U. S. No. 1 grade. Some of the more frequent appearing defects are sunburn, second growth, growth cracks, scab, wireworm injury, late blight, storage rots, skinned, bruised and cut tubers. Even if all the above defects were removed before the housewife gets them home, she may then be confronted with net necrosis, internal discoloration from vine killers, mahogany browning, hollow heart, black spot, *etc.* And when she cooks them they may be soggy ,turn dark, slough when boiled or have a repulsive flavor from the use of certain insecticides. Is there any wonder that potato consumption has decreased? And yet there are growers and others who maintain that the production problems are solved. That can hardly be true when we recognize the preceding statements in this paper.

* Paper No. 342, Department of Vegetable Crops, Cornell University.

Another reason for the decline in consumption of potatoes is the misleading notion that potatoes are fattening. Many fattening foods are eaten regularly by persons who habitually shun potatoes on the supposition that they are fattening.

The prevalence of many other competitive foods also has resulted in this decline in potato consumption. Forty years ago the average *per capita* consumption of food in America was only 10 pounds less than that of last year. Dozens of items are on the market today which were scarce or did not exist at all 40 years ago. But what have we done to compete with the offerings of canned foods, frozen foods and pre-prepared vegetables? Each year a number of appetite-tempting items are brought into the market by food processors to elbow their way into the 3400 calorie diet of Mr. and Mrs. America. And yet potatoes are marketed, as far as the housewife is concerned, in about the same way as they were 40 years ago. Of what other food product is that true? If the potato is to maintain its present rate of consumption or be increased, then some way will have to be found to make it as attractive to the consumer as are the many other new and convenient food items. Such items as pre-peeled potatoes, frozen french fries, potato chips and sticks and dehydrated mashed potatoes are helping to fill this need.

In some areas we have been building a program of spending as much or more money trying to find some use for our culls than we have on a research program whereby the percentage of culls may be permanently reduced and hence no longer present a major problem. I don't know of any other industry that does that. Price support programs whereby the grower could market inferior quality potatoes at good prices tend to stifle any serious consideration of improving quality of potatoes on our markets. This is beginning to change.

What Can We Do with Our Present Potatoes to Better Satisfy the Consumers?

Let's talk about cooking quality. Cooking quality is made up of (1) consistency, texture or degree of mealiness, (2) color after cooking and (3) flavor. Mealiness in potatoes today is at the lowest level in modern history. "Beauty is only skin deep" never applied more appropriately than to our present day potatoes. There has been no way by which the consumer could tell in advance what the cooking quality of any lot would be. Naturally then, she chooses the potatoes which have the best outside appearance. This will, of course, be varieties such as Chippewa, Katahdin and Sebago, rather than Green Mountain, Rural and Cobbler. Hence, the switch over from high cooking quality to lower cooking quality varieties.

The grower, of course, is easily converted to the newer varieties since yields usually are higher than from the older varieties.

Practically everything that has been done in so-called improvement of the potato has either neglected cooking quality or resulted in lowering the cooking quality. This, in no way, is criticism of potato breeders. Much research and commercial effort have been expended in dressing up the exterior of our potatoes by breeding for brighter skin, shallower eyes, regular shape, *etc.*, sizing, better packaging, brushing, washing, waxing, and now, believe it or not, dyeing them. But little or nothing has been done to improve the edible portion. In other words, we have done a pretty good job of dressing up that part of the potato which goes into the garbage. This, to me, means increasing deception to the poor unsuspecting consumer. Where would the egg industry be today if they had followed such a program of improving the appearance of the shell, the inedible portion, and neglected the interior of the egg? Quality of the edible portion was determined by the simple process of candling. The determination of specific gravity, total solids or starch content of potatoes by the potato hydrometer or other methods is similar to the candling of eggs. By the method of separating potatoes into various specific gravity groups, we can now "gaze" into the interior of the potato and give consumers what they want in the way of mealiness of the cooked potato.

It is normal for potatoes to vary in specific gravity; tubers from any one hill of potatoes differ in their total solids content. There is no valid argument against the use of specific gravity separation of potatoes. Although our potato grades do not allow varietal mixtures, it is worse, as far as mealiness is concerned, to have potatoes of one variety as they are normally grown than it would be to have several varieties together but separated into one specific gravity group. It is just as important to have this separation as it is to have pastry flour and bread flour in separate bags.

Mealiness of Potatoes. Determination of specific gravity or total solids content of potatoes by the potato hydrometer is an excellent, rapid method of determining mealiness of potatoes before they are cooked. This method is being used now by many potato chip manufacturers since there is good relationship between the average specific gravity of any lot of potatoes and the yield of chips obtained. This information has been supplied to members of the National Potato Chip Institute in a series of releases beginning in October 1949. A potato hydrometer also has been developed by the Institute and is now being sold by the N. P. C. I. Results on the value of separating lots of potatoes into several specific gravity groups and on the yield of chips obtained from them have been made available during the past two years. In addition, the high specific gravity potatoes

consume less oil in the chip frying process than those of lower specific gravity. Although this process of measuring the average specific gravity of lots of potatoes is very worthwhile, the method of separating lots of potatoes by brine solutions into several specific gravity groups is still more valuable and far-reaching. By this process, any lot of potatoes can be separated into groups and labelled according to their best cooking purpose such as "baking", "boiling and mashing" and "frying".

Grading Potatoes for Mealiness and Its Effect on Retail Sales. During the marketing season of 1949-1950 such a study was conducted at Cornell University to determine to what extent consumers would purchase potatoes separated into various degrees of mealiness by the specific gravity process and approximately how much of a premium consumers would be willing to pay to have such potatoes available. Potatoes which sank in a salt solution of 1.080 were designated "Bakers", those which floated at 1.080 but sank in 1.070 solution were termed "Boilers" and those remaining afloat in a solution of 1.070 were labelled "Fryers". Data were obtained for an 18-weeks period in two large retail stores where consumers were offered the choice of four lots of experimental potatoes in addition to the usual store offering. Three of the four lots were separated according to their degree of mealiness and the fourth was a check lot of non-separated potatoes.

During this period 7565 five-pound packages of experimental potatoes were sold. Forty-six and four-tenths per cent of those purchased were "Bakers", 28.3 per cent were "Boilers", 10.4 per cent were "Fryers" and 14.9 per cent were "Regulars" or unseparated. During the first 10 weeks' period when the five-pound bags of all lots were sold for the same price, namely 17 cents, 47.7 per cent of all experimental potatoes sold were Bakers; when the price of Bakers was increased to 24 cents for four weeks the Bakers comprised 46.7 per cent of all potatoes sold and when the price was further increased to 26 cents the Bakers made up 40.6 per cent of the total sales. This shows that the consumers were willing to pay seven cents more for 5 pounds of Bakers than for the same potatoes unseparated as to specific gravity without any reduction in volume of sales. Likewise, consumers paid four cents more for 5 pounds of Boilers than for the same potatoes unseparated. Even the "Fryers" sold for 2 cents more for 5 pounds than the unseparated potatoes without any decrease in sales.

These results show that consumers can now be supplied by using our present varieties, with potatoes which, as far as mealiness is concerned, will perform as desired when cooked in the proper manner. The Bakers can be guaranteed to be mealy when baked or mashed and the Boilers

and Fryers can be guaranteed not to slough and fall apart when it is desired to serve a whole, boiled potato. Hotels and restaurants will often pay a premium to be assured of such potatoes, and consumers willingly pay for this guaranteed performance.

Many Factors Affect Specific Gravity and Mealiness of Potatoes. Some of us seem to think that our potatoes have become less mealy during the past few years than they were formerly. Determination of specific gravity of thousands of samples of potatoes in New York State during the past 12 years indicates that total solids content of potatoes during the last several years has decreased. Typical examples are potatoes of the following varieties grown in the same location in 1940 and in 1950.

Variety	Specific Gravity	
	1940	1950
Sebago	1.098	1.082
Katahdin	1.092	1.083
Cobbler	1.085	1.082
Pontiac	1.081	1.071

Reasons for this decline are due largely to methods of growing potatoes today compared with those of ten years ago. Some of the factors which affect mealiness of potatoes are as follows:

(1) variety,
(2) temperature during the growing season, especially during the last few weeks,
(3) soil moisture (rainfall, irrigation),
(4) soil type and location (muck *vs.* upland),
(5) amount and analyses of fertilizers,
(6) date of planting,
(7) date of harvest,
(8) mulching,
(9) vine killers,
(10) maturity, and
(11) spraying program (fungicides, insecticides, especially DDT).

Cooking Methods Which Alter Culinary Quality. It has been shown that when peeled potatoes are boiled whole but slough or fall apart during the process, that the addition of small quantities of calcium chloride, calcium lactate or calcium sulfamate to the boiling water will reduce or prevent the sloughing. Many factors have been related to the after cooking

blackening of potatoes and we will mention some of them later. During the cooking process this blackening may be reduced or avoided by the addition to the water of small amounts of some acidifying agent such as lemon juice, vinegar or cream of tartar.

The after cooking blackening process is still not well understood. Without going into the various theories as to the chemical processes involved, I would like to enumerate here some of the possible causes of this widespread trouble. Some of the factors affecting after-cooking darkening are as follows:

(1) varietal characteristic,
(2) growing season temperature, especially the last few weeks,
(3) sunshine,
(4) fertilizers,
(5) pH of the tuber, and
(6) maturity of the vines and tubers.

What Can Be Done Immediately to Stimulate Potato Sales? Some factors which might be emphasized to assure that consumers receive potatoes which more nearly meet their needs are:

(1) Package potatoes with fewer defects.
(2) Market in size and type of container best suited to the consumer.
(3) Emphasize the non-fattening qualities of the potato. Compare it with other fattening food commodities which are eaten daily by persons who shun potatoes.
(4) Separate potatoes as to specific gravity and show the consumer how each fits a specific cooking purpose. Guarantee potatoes to be "mealy" or "to not slough when boiled whole", *etc.*
(5) By use of the potato hydrometer or other methods find lots of potatoes of high specific gravity and bring it to the attention of potato chip manufacturers, french fry folks and dehydrators of potatoes.
(6) Publicize methods of cooking which will reduce the appearance of after cooking darkening in potatoes.
(7) Encourage the pre-peeling, canning, frozen french fry, potato chips and sticks, and dehydrated mashed potato industries. Potentially they are the best things yet devised for the housewife, hotel and restaurant people to cut down their disagreeable and costly operation of preparing potatoes for the table. It is the best thing we have to compete with canned, frozen and pre-prepared vegetables which now are offered to all consumers most everywhere.

CHANGES IN SPECIFIC GRAVITY, STARCH CONTENT, AND SLOUGHING OF POTATOES DURING STORAGE

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(Accepted for publication June 14, 1951)

The value of the specific gravity method for predetermining the cooking or processing quality of potatoes cannot seriously be questioned. Numerous studies have shown that tubers of high specific gravity give a characteristically mealy product, whereas those of low specific gravity become watery or soggy when cooked. Furthermore, high density tubers give increased yields of chips (5), mashed potato powder, and other similar dehydrated products (1). The advantages of being able to measure and to separate high density tubers from those of low density is therefore readily apparent.

Although a general correlation between high specific gravity and mealiness has been noted, little attention has been given to possible imperfections in the relationship. It usually is assumed that a particular specific gravity rating indicates a special type of texture. It is possible, however, that tubers of the same density and variety may vary appreciably in their texture, or that the same tubers may change both in density and in texture during storage. Our data show that these variations do occur.

In our work on the texture of potatoes as indicated by their sloughing losses, we usually were able to separate tubers which would slough from those which would not, by differences in their specific gravity. Tubers of low specific gravity never sloughed, but the high density tubers exhibited a considerable variation in the degree of sloughing. The need for detailed information on the specific gravity-sloughing relationship, especially in the high specific gravity range, led to the present study. The study was concerned with the changes in a single lot of tubers which was divided and subjected to different storage conditions.

MATERIALS AND METHODS

Irish Cobblers, grown near Waterville, New York, in 1949, were divided by flotation in brine into three lots of specific gravity 1.085 and one lot of specific gravity 1.095. Tubers of low specific gravity were discarded. One lot of specific gravity 1.085 was stored at 75° F., a second lot at 50° F., and the third lot at 35° F. The relative humidities at the three temperatures were 53, 72, and 89 per cent, respectively. The lot of specific

[1] One of the laboratories of the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture.

gravity 1.095 was stored at 50° F. At periodic intervals, previously weighed 20-tuber samples were removed from each lot for study and analysis.

Sloughing losses were measured in triplicate with tissue specimens of nearly uniform density cut from the tubers, in a manner described by Whittenberger and Nutting (9). Only 3 or 4 specimens (about 10 gms. each) of the same specific gravity could be cut from an average-size tuber. The specific gravity of each specimen was determined, after which specimens of the same density were pooled for the measurement of sloughing loss and starch content. Tissue specimens rather than whole tubers were used because the latter were not sufficiently homogeneous in specific gravity. A tuber of specific gravity 1.095, for example, ranges in specific gravity from about 1.120 in one region to 1.060 in another. In contrast, the tissue specimens were nearly uniform in density.

From the tubers of specific gravity 1.085, tissue specimens of specific gravity 1.075, 1.095, and 1.100 were selected for measurement of sloughing loss and starch content; from the tubers of specific gravity 1.095, specimens of specific gravity 1.075, 1.100 and 1.110 were selected. For the sake of brevity, however, only part of the data will be reported in this paper. In cases where the tubers changed in density, test specimens of the original densities were selected for study, except where otherwise noted.

The Steiner-Guthrie method (6) was used for the starch determinations, and total dry matter was measured by drying the samples in an air oven for 16 hours at 150° F. and then for 2 hours at 266° F.

Changes in Specific Gravity and Sloughing

There was no change in the specific gravity of tubers stored at 35° F. (Table 1). However, tubers stored at 50° F. slowly increased in specific gravity, the original sample of specific gravity 1.085 attaining a value of 1.094 after 24 weeks of storage. Likewise, the specific gravity of tubers held at 75° F. increased. The increase was more rapid than that of the sample stored at 50° F. A second sample stored at 75° F. for 8 weeks (not shown in table 1) increased in specific gravity from 1.085 to 1.093. Since this sample had been stored previously at 50° F. until the dormant period had passed, it is not comparable with that shown in table 1. Small tubers increased more rapidly than did the large ones. Our results are not completely comparable with those of Terman *et al.* (7), who found that potatoes stored at 36°, 40°, and 50° F. increased in specific gravity.

The increases in specific gravity were correlated with shrinkage of the tubers. For example, the weight losses, including sprouts, of the 35° and 50° F. samples at the end of 24 weeks of storage were 2 and 25 per cent, respectively. About one-half of the 25 per cent loss was due to

sprouts and the remainder to loss of water vapor and carbon dioxide. The 75° F. sample (Table 1) decreased 8 per cent in weight in 8 weeks. Shrinkage was, of course, most pronounced after dormancy had been broken and the tubers had begun to sprout. There was but little shrinkage or change in specific gravity during dormancy.

Meanwhile, the extent of sloughing decreased in all samples during storage (Table 1). The most rapid decrease occurred in the tubers held at 35° F., whereas the least rapid change occurred in the samples stored at 50° F. The pH of the expressed juice of all samples remained relatively constant ,ranging from approximately 6.0 to 6.2.

TABLE 1.—*Changes in specific gravity and sloughing loss of potatoes during storage*

Temp. of Storage (F.)	Storage Period in Weeks							
	0		8		16		24	
	Spec. Grav.[1]	Sloughing Loss, Per cent[2]	Spec. Grav.[1]	Sloughing Loss,[3] Per cent[2]	Spec. Grav.[1]	Sloughing Loss, Per cent[2]	Spec. Grav.[1]	Sloughing Loss, Per cent[2]
35°	1.085	14	1.085	1.0	1.085	1	1.085	0
50°	1.085	14	1.085	7.8	1.088	7	1.094	4.0[5]
50°	1.095	26	1.095	20.6	1.097	15	1.102	8
75°	1.085	14	1.087	3.6	[4]	—	—	—

[1] Whole tubers were used.
[2] Dry weight basis. Tissue specimens of specific gravity 1.100 were used except in the case of the second sample stored at 50° F. In that case, specimens of specific gravity 1.110 were used.
[3] The difference required for significance at the 5 per cent level among the samples of this column was 2.9 per cent.
[4] At 75° F., the tubers did not remain sound for 16 weeks.
[5] The sloughing loss from tissues of specific gravity 1.110 of this sample was 4.3 per cent.

SPECIFIC GRAVITY AND STARCH CONTENT

To further an understanding of the causes for the observed changes in texture, starch and dry matter determinations were made of the tubers and tissue specimens used in this study. It was possible that some of the changes in texture which were not correlated with changes in specific gravity might be correlated with changes in starch content. In other words, it was desirable to test the reliability of the specific gravity method for estimating starch content. Accordingly, in table 2, the results obtained by the specific gravity method of von Scheele *et al.* (4) are compared with those of a chemical method (6).

The data show that the specific gravity ratings satisfactorily indicated the starch content both of freshly-harvested potatoes and of those stored at 50° F. However, tubers which were stored at 75° F. and had lost considerable weight contained more starch than was indicated by the specific gravity method. One probable cause for this is the increased proportion of skin or cork in a shrunken tuber, particularly if the tuber is small. Since the cork contains air and is of low specific gravity, a compensating increase in specific gravity of internal tissues must occur if the tuber is to remain of the same density. The concentration of starch therefore was greater than was indicated by the specific gravity rating. Data on peeled tissues substantiated this explanation.

The most serious shortcoming of the specific gravity method for estimating starch is revealed by the data on cold-stored (35° F.) tubers. Always the true starch content was lower than was indicated by the specific gravity method. The probable reason for this was that some of the starch was converted to sugar, which is similar to starch in density.

The starch content of cold-stored tubers could be estimated rapidly, however, if the soluble solids content as well as the specific gravity were known. If the soluble solids content (estimated with the Abbe refractometer) was subtracted from the dry matter content (estimated from specific gravity measurements), a value was obtained which closely approximated the starch content. As an example, the dry matter content of tissues stored for 8 weeks at 35° F. was 22.8 per cent, fresh weight basis, and the soluble solids content was 9.7 per cent. The estimated starch content was therefore 13.1 per cent, which compared well with the value of 13.5 per cent obtained by chemical analysis. The amount of non-starch insoluble solids was small and was neglected in the present case.

The soluble solids fraction as estimated with the Abbe refractometer certainly contained appreciable quantities of soluble proteins, pectins, and mineral salts, as well as sugars. Because the scale of the refractometer was calibrated for sugars only, it was therefore necessary to apply a correction factor, or to recalibrate the scale. By gravimetric analysis, this factor was found to be about 0.93 for tubers stored at 35° F. In other words, the scale readings were multiplied by 0.93 for correction. The correction factor for tubers stored at 50° F. was 0.88.

The specific gravity method for estimating starch was almost equally applicable to unpeeled tubers and to peeled tissue specimens (Table 2). As noted previously, however, the adverse effect of a relatively high proportion of skin (storage at 75° F.) was minimized when peeled tissues were used. The tissues, of course, were not permitted to dry or to soak for even one minute either in water or in salt solution.

TABLE 2.—*Representative data comparing the specific gravity and chemical methods for determining the starch and dry matter content of Irish Cobbler potatoes stored under various conditions.*

Storage History	Specific Gravity	Starch, Per cent[1]		Dry Matter, Per cent[1]	
		Specific Gravity Method[2]	Chemical Method[3]	Specific Gravity Method[2]	By Oven Drying
Whole tubers					
Original	1.085	14.8	14.9	21.2	22.0
"	1.095	16.8	17.1	23.3	23.1
35° F. 8 weeks	1.085	14.8	12.4	21.2	21.6
" 16 "	1.085	14.8	11.1	21.2	21.3
50° F. 16 weeks	1.085	14.8	15.2	21.2	21.3
" " "	1.095	16.8	16.5	23.3	23.0
75° F. 8 weeks	1.085	14.8	16.8	21.2	23.4
" " "	1.100	17.8	19.6	24.4	28.2
Tissue pieces					
Original	1.075	12.8	12.1	19.1	18.9
"	1.110	19.8	20.4	26.5	27.2
35° F. 8 weeks	1.075	12.8	9.5	19.1	18.4
" " "	1.100	17.8	16.0	24.4	25.1
50° F. 8 weeks	1.075	12.8	12.2	19.1	18.0
" " "	1.100	17.8	18.6	24.4	24.8
75° F. 8 weeks	1.075	12.8	12.2	19.1	18.9
" " "	1.100	17.8	18.4	24.4	25.8

[1] Fresh weight basis.
[2] The graph of von Scheele *et al.* (4) was used for both whole tubers and tissue pieces.
[3] The method of Steiner and Guthrie (6) was used.

In general, the specific gravity data reliably indicated the dry matter content of the tubers, even of those stored at 35° F. (Table 2). Samples showing the greatest variation were those in which the skin cork had become the most concentrated (storage at 75° F.). The data fitted the curve of von Scheele *et al.* (4) better than they did the curve of Dunn and Nylund (2). Both the starch and dry matter data tended to be somewhat higher than that of von Scheele in the upper range, and somewhat lower in the lower range.

An interesting feature of the present study was the good correlation obtained between soluble solids content and specific gravity within the tissues of a single tuber. For example, tissue specimens of specific gravity 1.120, 1.110, 1.085, and 1.060 were cut from different regions of a tuber (specific gravity 1.095) stored at 50° F. for two weeks. The soluble solids contents of the specimens were 8.1, 7.5, 6.6, and 5.6 per cent, respectively. This may mean that the cells in the tuber which synthesize

the most starch also contain the greatest concentrations of proteins, pectins, and mineral salts. The correlation held also when whole tubers varying in specific gravity were compared. The significance of the correlation and the possible effects of these materials upon texture are not clear.

Effects of Changing the Storage Temperature

The tubers used in obtaining the data of table 3 were stored successively at 50° F. for 2 weeks; at 35° F. for 16 weeks; and at 75° F. for 2 weeks. They showed almost no change in specific gravity during these periods. In contrast, they changed markedly in degree of sloughing and in starch content. At the low temperature their degree of sloughing and starch content decreased, but when the tubers were returned to warm (75° F.) storage, they increased both in sloughing and in starch content. A greater increase in sloughing was observed in a previous study (9). Meanwhile, the changes in soluble solids content were opposite to those of the starch. If the tubers were reconditioned at 75° F. for more than two weeks after cold storage, they showed a tendency to decrease in specific gravity.

Table 3.—*Effects on potatoes of a sequence of storage temperatures*

Factor Observed	Changes in Temperature and Duration of Storage		
	1. —> 50° F. 2 weeks	2. —> 35° F. 16 weeks	3. 75° F. 2 weeks
Specific gravity[1]	1.085	1.085	1.085
Sloughing loss[2]	5.5	0.8[4]	1.4[4]
Starch[3]	17.2	13.6	16.7
Soluble solids[3]	6.7	9.9	7.2
pH of fresh juice	6.0	6.1	6.4

[1] Whole tubers were used.
[2] Per cent, dry weight basis, of tissues of specific gravity 1.095.
[3] Per cent, fresh weight basis, of tissues of specific gravity 1.095.
[4] Significantly different at the 5 per cent level.

Discussion

The results shown in tables 1 and 3 point out certain limitations of the specific gravity grading method which to our knowledge are not mentioned in the current literature. (1) The relationship between specific gravity and sloughing is a changing one, and is dependent largely upon the physiological condition of the tubers. (2) Sloughing may decrease or increase with no change in specific gravity. (3) Sloughing may actually decrease as

specific gravity increases, or, in a sense, there may be under certain conditions an inverse relationship between specific gravity and sloughing.

These observations appear to be at variance with the generally accepted concept concerning specific gravity and texture. It is possible, however, to reconcile our findings with those of previous investigators. Despite the quantitative differences in the relationship between specific gravity and sloughing among our samples, within any one sample the correlation between specific gravity and sloughing was excellent. To illustrate, sloughing losses from tissues of specific gravity 1.100, 1.095, and 1.075 were originally 14.4, 8.9, and 1.2 per cent, respectively. After storage of the tubers for 16 weeks at 35° F., the corresponding sloughing losses were 1.2, 0.9, and 0.5 per cent.

It is to be noted that some of our treatments of potatoes were extreme. For instance, a weight loss of 25 per cent during storage would not be experienced in commercial practice. Such treatments are of value, however, in that they serve to magnify small differences which ordinarily would be overlooked and which sometimes lead to an understanding of fundamental problems. In the present case, an understanding of the factors which govern the texture of potatoes is involved.

The hypothesis we have adopted to account for the observed changes in potato tissue texture is based upon differences in the pressure developed within cells by the swelling of starch granules during cooking, and upon differences in the cells' capacity to tolerate pressure. If a cell contains a relatively large quantity of starch, the pressure developed will be great, and the cell will become severely distorted. As a result of this, the intercellular cement may fracture and the cell may separate or slough from the main body of tissue.

In tubers stored at 50° F. and above, sloughing decreases (although specific gravity increases) for the following reasons: (1) tissues of a stored tuber constantly are using up starch in respiration and frequently in sprout formation; (2) meanwhile, the number of cells in the tuber does not change; (3) this means that the amount of starch in each cell constantly decreases; (4) at the same time, the tissues shrink; (5) thus the cells have an increased capacity for expansion at the same time that they contain less starch (swelling agent); (6) in addition, the swelling power of the starch may be diminished slightly by an increased concentration of mineral salts (3); (7) therefore, less pressure is developed within each cell, less distortion of the cell and splitting of the intercellular cement occurs, and the degree of sloughing decreases. Conversely, we would expect the maximum degree of sloughing to occur at or near harvest time when each cell is fully distended and contains its maximum amount of starch.

The sequence of events leading to the decreased sloughing of tubers stored at 35° F. probably is as follows: (1) some of the starch is converted to sugar; (2) this (together with respiration) decreases the amount of starch in each cell; (3) in addition, the presence of sugar diminishes, in a small measure, the capacity of starch to swell (8); (4) accordingly, there is less pressure developed in each cell and less sloughing occurs. If the tubers are transferred to storage at 75° F., sloughing increases owing to the reversal of the same mechanism. The sugar is reconverted to starch more rapidly than it is used in respiration.

The cause for the imperfections in the specific gravity-sloughing relationship is that specific gravity data alone do not reveal the changes in the amount of starch in individual cells. Although the data do reveal fairly accurately the starch content of whole tissues stored at 50° F. or above, a distinction must be made between the per cent starch in a tissue and the relative amount in each cell. For example, before storage a tuber weighing 100 grams may contain 15 per cent, or 15 grams, of starch. After storage the tuber may weigh 80 grams and still may contain 15 per cent of starch as revealed by specific gravity data, but this now is equivalent to only 12 grams of starch. In the latter case, each cell would contain less starch than originally, and less sloughing should be expected. Although the relative amount of starch in each cell cannot be measured directly or conveniently, it apparently is a factor of great importance in determining tissue texture.

Corrective measures for improving the accuracy of the specific gravity grading method appear to be simple. In the present case, at least, it is merely necessary to recognize that the same potatoes may change both in specific gravity and in texture during storage, and that the changes occur in an orderly and predictable fashion. Therefore a number of standard curves may be prepared for converting the specific gravity ratings into terms of texture or of starch content. One curve may be applicable to potatoes stored a definite time at 35° F.; a second curve may apply to dormant tubers stored at 75° F.; and so on. At the present time just one curve is used for tubers which may differ widely in age, in storage history, in shrinkage, and in physiological condition. Some of the disadvantages of doing this have been pointed out in this paper. The currently used curve of von Scheele seems to be most applicable to freshly harvested potatoes and to those stored at 50° F. For other potatoes, restandardization of the curve may result in greater accuracy and in wider use of the specific gravity grading method.

Our hypothesis on texture needs to be tested further. Different varieties of potatoes should be used, and different storage conditions should be studied. When different varieties are compared, their tubers should be identical in age and in storage treatment.

That pectic compounds, especially those composing the intercellular cement, play an important role in determining texture cannot be denied. Without the cement there would be no tissue cohesiveness, no tissue texture. In our concept of textural differences, however, the pectic substances are assigned a passive rather than a causative role, and they are regarded as a relatively constant factor among others which vary. In other words, variations in the starch content of cells have a greater effect upon texture than do variations in the pectic substances. The starch acts principally by developing intracellular pressure which weakens or fractures the pectic cement to varying degrees. If pectic substances were responsible for the changes in texture, one might expect the potato to become increasingly mealy during storage, as do apples. The contrary is true. Furthermore, it is difficult to explain the textural changes which occur in potatoes stored at alternating high and low temperatures in terms of pectin chemistry. The textural changes parallel the changes in starch content of individual cells.

Acknowledgment. We are grateful to Dr. C. O. Willits and Mrs. Mildred Gaspar for the starch and dry matter determinations.

Summary

Certain limitations of the specific gravity method for predetermining the sloughing loss from Irish Cobbler potatoes are revealed. The relationship between specific gravity and sloughing depends partly upon the physiological condition and storage history of the tubers. The extent of sloughing may decrease or increase without any change in specific gravity, or sloughing may even decrease as specific gravity increases. The accuracy of the specific gravity method for indicating starch content also may vary with the storage of tubers. The method is least accurate with tubers stored at a low (35° F.) temperature.

An hypothesis concerning the general nature of potato texture and the mechanism of change in texture is presented. The hypothesis is based upon differences in pressure developed in cells by the swelling of starch during cooking, and upon differences in the capacity of the cells to tolerate pressure. The relative amount of starch in individual cells rather than its concentration in whole tissues determines texture. The amount of starch in a cell may decrease at the same time that its concentration in a tissue increases. For instance, during storage at 75° F., starch in cells is used continuously in respiration and often in sprout formation. This change in starch content is not revealed by specific gravity data because the tuber and cells shrink, become more compact, and may even increase in density. Since the number of cells in a tuber does not change, the amount of starch in each cell decreases, less pressure is developed when the cell is cooked, and a change

toward a waxy texture results. Thus, factors which decrease the amount of starch per cell (*e.g.*, sprout formation, storage at a high (75° F.) or low (35° F.) temperature) hasten the development of a less mealy texture, and factors which retard the decrease (*e.g.*, dormancy, storage at 50° F.) help to maintain the original texture.

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"POTATO PROMOTIONAL ACTIVITIES: HOW — AND WHEN?"

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Perhaps few potato growers realize the extent to which their product is losing favor with the public. Those who watch national marketing trends in the fresh fruit and vegetable business believe that the attitude of many customers toward potatoes (and potato growers) has changed to ill-will and even resentment. Otherwise, what is the cause of the accelerated decline in *per capita* potato consumption, which has gone down nearly one-fifth in the last five years?

USDA's official potato goal announcement for 1951 declared that we need only 335 million bushels to satisfy present consumption demands. If these demands keep on declining at the present rate, within ten years our market will have shrunk to less than half the production we need today.

Why Aren't Potatoes Popular?

People who make public relations their business think they see certain causes for the public's attitude. One such cause is the Government price support program, recently terminated. Regardless of how the growers felt about it, or the arguments for it from their viewpoint, consumers who outnumber growers more than 500 to 1, disliked the price support program because of its cost, its supposed effect on retail prices, and its great waste. Typical of the mounting tide of public criticism is a recent story syndicated by a national newspaper chain, from which the following is quoted:

"The Government's potato price support program, dying without tears or eulogy June 30, has cost U. S. taxpayers a total of 540 million dollars during its eight-year life. That's enough money, at current prices, to dot the skies with 5400 F-80 Shooting Stars. The program took approximately 500 million bushels of potatoes off the market to hold up prices to potato growers — more than 3 bushels for every man, woman and child in the United States. And of this 500 million, 89 million — or nearly one-fifth — were dumped".

Another cause of unpopularity is the mistaken notion that potatoes are excessively fattening. This erroneous assumption is kept alive by too many doctors who single out potatoes as the one thing to be avoided in a non-fattening diet, ignoring or at least minimizing the high caloric value

of similar foods. Most healthy people leading physically inactive lives will gain weight if their caloric intake is greater than their energy output. But it seems easier (and perhaps more profitable) for some members of the medical profession to make a bugaboo of potatoes than to try to get this simple fact appreciated. Good potatoes, properly cooked, can play an important part as a nutritious, protective, body-building food for millions of people, but we aren't telling them much about it.

What's the Matter with Public Quality?

This question leads students of public relations to another point, and that is quality. When you go to buy potatoes in the retail store, do you (or your women-folks) find an attractive, clean, well-graded product? If they are in consumer packages, can you buy them without hesitation, knowing the quality will be uniformly good? Is there a generous assortment of different grades, sizes or varieties, plainly marked regarding the price? Is there ever any suggestion ("guarantee" might be too strong a word) that they are adapted to a specific cooking purpose, such as boiling, mashing, or frying? Or, if you are eating in a restaurant, are potatoes available in a variety of forms, are they well cooked, served hot and do they taste good? Yet those are simple merchandising principles which have long been applied to competing foods and which invariably build consumer confidence and sales."

Potato Business Now "On Its Own"

Starting with this year's crop, potatoes are again "on their own." Our only customers will be the people who buy our product to consume it or who resell it to consumers. This fact will become more apparent as time passes. Will we at last turn our attention to the development of sound merchandising practices, or shall we continue to clamor for political relief?

The first thought of most of us when sales turn sour is a national advertising campaign. The United Fresh Fruit and Vegetable Association endeavored for more than two years to promote such a project for potatoes. The practical question is not whether advertising would effectively persuade the American people to buy and use more potatoes, but whether the potato business will provide the money to set such a campaign going and keep it up for the several years which would be necessary to make it effective. Continuity is even more imporotant than the initial start; you can't make long range advertising plans without a corresponding long range income plan to pay the bills.

Maine and Idaho have had tax-supported advertising programs on a state basis for about fifteen years. Colorado's San Luis Valley finances a

National Advertising Still in the Future

smaller program on a somewhat similar basis. Such state laws usually provide that the expenditure of tax money shall be limited to the products grown in that state, and each area is inclined to contend that its potatoes are best. Yet declining *per capita* consumption affects potato production in all states, and an increase in consumption would benefit all producing areas. Financial support for a national campaign requires that growers look at the consumption problem on a broader scale, rather than as it may apply to any particular state or its product. The development of such a viewpoint is likely to take time.

Doing with What You Have

If a national advertising campaign is not immediately possible, it doesn't mean that nothing can be done. A system of quality control at shipping point can go a long way toward insuring delivery of the kind of potatoes you'd want to buy yourself .More people in the potato business can, if they will, support trade groups in their effort to insure better protection and more careful handling of the crop while in transit or in retail or wholesale establishments. Individually and through trade groups they can support various efforts at consumer education which cost less than paid newspaper and magazine space.

Just as an example, the United Fresh Fruit and Vegetable Association thought it should do something about helping the retailer sell more fruits and vegetables. It took the initiative. It developed a program; it sought the advice of industry leaders; and it enlisted the support and cooperation of the U. S. Department of Agriculture. The result is that UMI-USDA retailer training schools have been held in more than 109 cities, in 36 states. More than 25,000 retailers have attended these schools and fully 3,000 executives, employees and salesmen of wholesalers have taken the same training. Last year the Department made a survey of this training work. It wanted to find out what returns were received for the money it is spending on this program. Briefly it found that 96 per cent of the retailers reporting showed increased sales and 95 per cent reported savings from reduced spoilage. The replies received covered more than 1800 stores. Potatoes, accounting for the largest volume of any vegetable, naturally received a full share of these benefits.

Cultivate the Institutional Market

Next to our sales through retail stores, the most important outlet for potatoes is represented by the public feeding industry. According to statistics, there are fully 525,000 public feeding establishments in the

United States, which annually provide about 40 billion meals for our people. This is approximately a quarter of all food consumed in this country. Experts in that field have told us that 63 million customers sit down at the tables and counters of our restaurants every day. What they find there — good or poor — has influence upon the whole consumption rate of the same food. If they find really wonderful hashed brown, French fried or baked potatoes in the restaurants they want to have the same at home. If they find gummy or watery mashed potatoes, or greasy and discolored fried potatoes they are not inclined to want any more of the same even in their own homes.

The restaurant operator is constantly worried by increasing food and labor costs. In that industry, more than 75 per cent of the business is done by less than 20 per cent of the firms in it. The industry possesses an effective trade organization whose specialists tell us that the increased use of potatoes, together with modern methods of storing and handling them, can effect important savings in both labor and food costs. They have assisted us in launching research projects calculated to provide methods of pre-testing potatoes for cooking quality as well as to promote potato usage in other ways. The potato industry could well study the institutional market more thoroughly and do more to cultivate it.

Besides training grocers in effective produce selling, the United is also doing many other things with the small budget its income permits. It issues a Monthly Supply Letter telling what our industry has to sell and when it is in abundance. This Supply Letter is reproduced by the National Restaurant Association and goes to 6,000 leading restaurants. It also goes to 280 newspapers, 62 radio stations, 43 magazines, 390 hospital dietitians, 200 wholesalers and 191 others including food writers. It guides them in their purchases and calls their attention to products such as potatoes which may be plentiful or in season. It goes only to those interested enough to ask for it.

We also issue what we call Menu Ideas. This covers five commodities each month, and is prepared by our Staff Dietitian. It is received enthusiastically by the women who run the food columns in newspapers. Menu Ideas is now going to 261 newspapers, 26 magazines, 56 radio stations, 358 hospitals, 182 wholesalers and 156 others including syndicate writers. Potatoes receive their fair share of the publicity in Menu Ideas.

Early this spring the United published a table, "More for Your Money" showing that a dollar's worth of potatoes contained not only more calories but more carbohydrates, phosphorus, iron, thiamine and niacin than were available in 13 other products. Only one other food provided more protein. The table proved conclusively that potatoes are the best bargain in the family's food budget today. The table was printed in quantity and was

circulated to a long list of newspapers, food publications, food editors, dietitians and food buyers. Potato people can advance the interests of their business by seeing that such facts and figures receive wider publicity.

Viewing the potato industry as a whole, only a comparatively small number of its leaders are contributing their time, ideas and money to help trade organizations fight a "holding action" until the industry unites in a national merchandising program comparable to the size of the problem. Declining potato consumption is a hard fact and not a theory. It means that, if the decline is unchecked, potato production must be drastically reduced either voluntarily or by ruthless competition.

Consumers of food demand clean, well-graded, attractive merchandise, honestly packed. They'd like to know in advance that it will cook well for specific purposes, and taste good when they eat it. They're accustomed to these things when they buy other foods and they don't think potatoes should be any exception. Promotional activities that are soundly planned, adequately financed and aggressively conducted can help satisfy these natural consumer desires, and build business. The answer seems to rest with potato people themselves.

Erratum

In the August, 1951 issue, in the article entitled, "Mechanical Separation of Potatoes into Specific Gravity Groups Shows Promise for the Potato Chip Industry" by R. Kunkel, J. Gregory and A. M. Binkley, table 6, page 694 should read as follows:

Table 6.—*The effect of specific gravity on the absorption of ether extractable fat by potato chips*

Specific Gravity	Mean Per cent Fat**
1.0916	32.64 ± .65
1.0777	37.05 ± .61
Diff. 0.0139	4.41

INDEX

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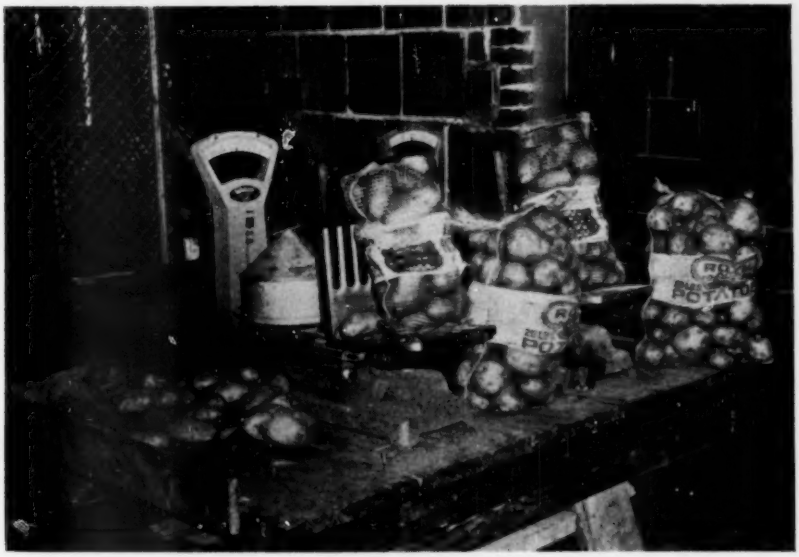

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